

Chapter 9

Production Systems, Nutrient Dynamics and Organic Farming

☆ *R. Dhanapal, P. Subramanian, Surekha, Ravi Bhat, Alka Gupta and Murali Gopal*

1. Introduction

The average productivity of coconut in India is 8303 nuts ha⁻¹ year⁻¹. The low national average is mainly due to the presence of senile and unproductive palms, low genetic potential of native palms, presence of diseases, pests and cultivation in marginal and sub-marginal lands along with lack of adoption of scientific cultivation practices with regard to irrigation and manuring. Planting high yielding varieties and adopting modern production technologies *viz.*, basin management, integrated nutrient management, organic recycling, coconut based cropping/farming system, integrated pest and disease management, irrigation management, drip fertigation, soil and water conservation measures etc., will enhance the productivity of coconut.

2. Climate

Coconut palm is mainly a crop of the humid tropics and is distributed between 23° north and 23° south of the equator and altitudes of about 600 m from the mean sea level (MSL). The crop is confined up to 750 m MSL in the majority of Asian and South Asian countries (Cooke, 1936), where as in Africa it is cultivated even at an elevation of 1350 m MSL. However temperature plays a major role to decide the elevation at which the crop can be grown successfully. The required average temperature is in the range of 27-32°C with a diurnal variation of not more than 7°C. Minimum temperatures above 10°C trigger flowering and temperatures <10°C for 1 month cause nut fall, while temperatures >40°C during April to July in the tropics decrease functional leaf area index, dry matter production and nut yield.

Annual rainfall requirements range between 1000 mm and 2500 mm and sunshine is required, preferably in excess of 2000 hours with 120 hr. of sunshine per month (Child, 1974; Persley, 1992; Jeganathan, 1993; Rajagopal *et al.*, 2006). Ideal relative humidity is 80-90 per cent and RH below 60 per cent results in stomata closure that restricts transpiration. Humidity level close to saturation point exposes the palm to a number of diseases.

3. Soil

Coconut palm is known for its adaptability to a wide range of soils and varying soil environment. John (1949, 1952) indicated that the best soil for coconut is rich alluvium or loam having proper soil moisture and drainage. The backwater areas of Travancore, Cochin, Malabar, South Kanara and deltaic tracts of the important rivers of India were highly suitable for coconut cultivation. Coconut also thrives and yields well in lateritic loamy, or black clayey soil on bunds of canal, channel and tanks and on sandy soil, especially of the littoral type provided there is assured supply of good underground water within easy reach of roots and the trees are properly manured. Magat (1993) defined the best suitable soil for coconut cultivation in the Philippines as coastal flat or inland flat land with at least 80 cm soil depth, alluvial and lime stones-derived soils with pH close to alkaline with average to moderate fertility level. In Sri Lanka, coconut is grown in different soils (Jeganathan, 1993). The coastal sands- sandy regosols (Entosols), lateritic soils and lateritic soils with plinthaite (Ultisols) are poor in fertility and are subject to heavy leaching. Deep loamy soils, alluvial soils and gravelly soils - reddish brown earth (Alfisols) are the best soils for growing coconut. Cosico and Fernandez (1983) found that, the average nut yield of palms growing in soils identified as Entisol, Alfisol, Ultisol, Inceptisol and Vertisol all over the country did not differ significantly (37 to 43 nuts/tree/year). However, if total farm productivity (coconut + intercrops) is considered, soils with higher base saturation as Alfisol and Inceptisol could be more suitable for coconut inter cropping, a farming system in which competition for nutrients is stronger. Generally, soil having 1-1.5 m depth, good drainage, rich organic matter content, good fertility, water holding capacity and a pH range of 5-8.5 is suitable for growing coconut. The movement of soil water is most essential to ensure proper growth and development of coconut as the root is unable to withstand stagnated water (Copeland, 1931; Sampson, 1923). Coconut is a semi halophyte that can tolerate fairly high amount of salts in the soil. Coconuts grow without any permanent physiological injury, even when their roots are in contact with high salt concentration (Sankaranarayanan *et al.*, 1958) and are known to withstand fairly high salt concentration of 10,000 ppm (Krishnamoorthy and Premanathan, 1968). If salt is present beyond this level suitable ameliorative measure like leaching of excess salts or application of gypsum, sulphur and acid forming chemical fertilizers need to be adopted. Heavy clay soil, clay sub soil and peaty soils should be avoided for growing coconut. Pandalai *et al.* (1953) emphasized that with suitable cultivation, conservation, adopting amelioration measures and manuring all normal soils could be used for coconut cultivation.

4. Nursery Management

Coconut being a perennial crop, the performance of the new progeny can be judged only several years after planting. If the seed nuts are of poor quality the new plantation will be an uneconomical causing considerable loss of time and money to the growers. Hence, healthy and good quality planting material is the foundation of successful coconut plantations. Seed gardens should be situated under average condition without heavy manuring or irrigation and free from pest attack, disease incidents, and with a higher proportion of regularly high bearers. Selection of mother palms is basically decided by the nut production and copra content. The critical value of nut production for selection of mother palm varies worldwide. In India, mother palms with an annual yield of more than 80 nuts under rainfed and 120 nuts/palm under irrigated conditions coupled with copra content not less than 150 g/nut will be selected for seed nuts. In Sri Lanka, the basis for selection of mother palm is an annual yield of not less than 75 nuts/palm with an average weight of 680 g (CRI, 1954) and in Malaysia, 100 nuts with wet meat content of 500 g (Smith, 1933). Palms located near cattle shed/compost pit, palms which produce barren nuts or those shedding large number of immature nuts and old palms should not be considered to collect seed nuts. Palms with at least 30 fully opened leaves, having umbrella shape, oriented in all direction, short, strong petiole and broader leaf base is ideal. Bunch stalk should also be short, stout and strong.

The proper time for the collection of seed nut is likely to vary according to the seasonal condition of the locality. In the areas receiving south west monsoon the seed nuts should be collected from December to April whereas in the areas receiving north east monsoon the nuts may be collected from May - July for better quality seedlings. However, there is no harm in collection of seed nuts in other months where there is peak coconut yield only fully matured 12 months old nuts should be harvested without damaging the nuts. Medium sized nuts with nearly round or spherical shapes should be selected and nuts of irregular shape, size are discarded (Smith, 1933).

Seed nuts can be sown in flat beds in a well drained coarse textured soil and in raised beds where the problem of water stagnation exists. In Sri Lanka the nurseries are located on loamy soil. In such soil, it is advisable to remove soil to a depth of 0.3-0.5 m and fill with sand. As a precaution against white grubs and termites, the soil should be drenched with suitable insecticides. Seed nuts should be planted in long, narrow beds at a spacing of 40 cm × 30 cm during May-June either vertically or horizontally in trenches of 20-25 cm depth. In Godavari belt of Andhra Pradesh and Orissa, India where much older seedlings are preferred for field planning, 0.9-1.5 m spacing is followed between seedlings. In Sri Lanka, planting of nuts giving 22 cm spacing between the nuts in the row and between two row is recommended. Nursery should be kept free of weeds, the beds are to be mulched and shade should be provided during post monsoon season. Coconut leaf mulch has been reported to promote early and better germination, good growth of seedlings and high percentage of good seedlings (Lyanage, 1952; Verghese *et al.*, 1953; Aiyadurai, 1954). The beds should be irrigated once in 2-4 days with about 10 mm of water for each irrigation. In porous soils like sandy and laterite the frequency of irrigation should be more.

Though it was reported that fertilizer is not essential for raising of nursery (Sampson, 1923; John, 1952), Nelliath (1972) recommended the application of NPK fertilisers in the months of December, February and April to supply 40 kg N, 20 kg P_2O_5 and 40 kg K_2O per application per ha in nurseries where seed nuts are planted in the month of May-June. Further studies conducted indicated that soil application FYM 25 t/ha along with 80 and 160 kg of Nitrogen and Potassium in 3 splits is advantageous in producing seedlings with high vigor (Srinivasa Reddy *et al.*, 1998). Nursery manuring is recommended and practiced in Sri Lanka. The nuts that have not sprouted till the period of 5 months should be removed. Deformed and stunted seedlings should be discarded and those that have germinated early should be selected. In India, one year old seedling with vigorous growth, having six to eight leaves and 10 cm girth at the collar, early splitting of leaves (Figure 9.1) should be selected as these are the good indicators of the rapid developers and early bearers.



Figure 9.1: Good Quality Seedlings.

Seedlings can also be raised in polybags. Pre germinated sprouts of 8-10 cm long are transplanted in 500 gauge poly bags of size 60 cm x 40 cm with 8-10 holes at the bottom. The potting mixture is the mixture of top soil, sand and compost in 2:1:1 ratio (Krishnakumar and Reddy, 2006). The advantage of poly bag seedling is the absence of transplanting shock and the seedlings are with better vigor. The disadvantage is in transportation and increase in the cost of seedlings. An additional advantage is that biofertilizer like PGPR consortia, VAM and P solublizers can be introduced in the polybag before field planting for better establishment of the garden.

5. Spacing and Planting

Gently pulled out seedlings from the nursery should be planted as early as possible, preferably before 10 days (Aiyadurai, 1954). The spacing adopted is found to vary from country to country and in the same country from region to region. In

India, the seedlings are planted in the main field by following square, triangular or rectangular system. Most of the existing coconut plantations are planted in the square system at spacing of 7.5 m x 7.5 m. Adoption of hedge (rectangular) system of planting coconut with wider row spacing and rows oriented in east west direction would increase light availability to intercrops (9.0 m x 6.5 m = 170 palms). This would facilitate growing annuals and perennials right from the time of planting coconuts. Triangular system of planting (equilateral triangle) accommodates more palms than square system of planting. However, it interferes with the cultural operations and growing of intercrops. In Sri Lanka, palms are planted at a spacing of 8 m x 8 m (square planting), 8.5 m x 8.5 m x 8.5 m (triangular system), 7.3 m x 8.5 m (rectangular system) and 7.3 m x 9.2 m or 7.3 m x 11.1 m of spacing to adopt inter cropping is recommended. In general the spacing followed in different countries varies from 7.0 m to 11.0 m in different systems of planting.

In Sri Lanka and India, planting is generally done during the beginning of south west monsoon season (May-June) or north east monsoon season (October-November) where as in water logged areas, planting can be taken up towards the end of the monsoon. Seedlings will be planted in 1 m x 1 m x 1 m in normal soil (Figure 9.2) and large pits of 1.2-1.5 m³ in rocky or hard (laterite) soil. In coastal sandy soils the size of the pits is 0.75 m x 0.75 m x 0.75 m. In Sri Lanka also the pit size varies with the soil type. Seedlings will be planted in 0.9 m x 0.9 m x 0.9 m and 1.2 m x 1.2 m x 1.2 m pits in sandy, loamy soil and gravelly soil respectively. In India, these pits will be filled with mixture of top soil and FYM or any compost to a height of 60 cm below ground level whereas in Sri Lanka, pits are filled with 1 kg dolomite, 5 kg organic manure and 1 kg young palm mixture (250 g urea, 750 g rock phosphate and 250 g muriate of potash) mixed top soil and seedlings will be planted in the centre of the pit. In Sri Lanka, seedling is planted about 20-30 cm below ground level and in Malaysia, the seedlings are planted such that the top of the nut is just above the ground level. In water logged soils mounds are made and seedlings are planted in the centre of the mound. In laterite areas 2 kg common



Figure 9.2: Planting of Coconut Seedling in 1 m³ Pits.

salt per pit can be applied and to conserve soil moisture 25-30 coconut husks can be buried per pit (CPCRI, 2012).

6. Under or Replanting

Replanting or under planting is necessary when the yield declines due to old age, long term neglect and continuous exposure to adverse conditions. Old palms should be removed in stages over a period of three to four years from the under planted garden. Mark the area to be planted. Remove very poor yielder and those very close to the planting pit. Plant the seedlings in the usual way one third of the old palms have to be removed each year during 2, 3 and 4th year after planting. If the existing garden is irregularly spaced, remove old palms within 1 m radial distance in first year, 2 m distance in second year and 3 m distance in third year and the rest in the fourth year. Generally flowering is delayed in under planted palms. In Sri Lanka, this will be taken up to 5-6 years by removing gradually *viz.*, after 1st and 2nd year 15 per cent, 3rd and 4th year 20 per cent and after 5th year remaining plants will be removed.

7. Irrigation

Coconut produces on an average one leaf and one inflorescence in every month and about 12-15 inflorescences are produced in a year. It takes about 44 months for an inflorescence bud to grow and develop to produce mature nuts. Since a palm produces an inflorescence every month, its crown has inflorescences at different stages of development throughout the year. Unlike field crops coconut does not have any critical period for water and nutrient requirement due to perennial nature, continuous production of leaves and inflorescence throughout the year and presence of bunches with different growth stages on the palm. Hence it is essential to provide irrigation during the non rainy season to maintain optimum soil moisture and regular application of nutrients to make the nutrient available throughout the year for high coconut productivity. In India, in the west coast region coconut is grown as a rain fed crop compared to east coast region where it is grown predominantly under irrigated condition. Saseendran and Jayakumar (1988) computed the mean yearly consumptive use of coconut to be 1,126 mm (37 l/palm/day for a basin area of 1.2 m). The yearly irrigation requirement was estimated to be 4,656 l/palm spread over the non-monsoon months of December to May. The importance of irrigating coconut for a sustained yield has been emphasized by many researchers in different countries (Wardlaw and Mason, 1936; Dhanapal *et al.*, 2002, 2004).

Irrigation management generally depends on soil characteristics (water holding capacity, texture, structure, depth, infiltration rate, land topography and depth of water table), weather parameters (rainfall, temperature, relative humidity, wind velocity and radiation), rooting pattern of crop and source of irrigation. Hence the system of irrigation should be selected very carefully. An ideal irrigation system will be the one in which water is supplied at the same rate at which it is absorbed by the palm. Irrigation methods commonly adopted in coconut gardens are flooding, basin, sprinkler or perfo-sprays and drip irrigation (Dhanapal, 2004). Yield became stable under adequate irrigation water supply during different periods of the year.

The annual irrigation and water requirements during the non-rainy period were determined as 538 mm and 1093 mm, respectively. The consumptive use during this period was estimated at 272 mm with an IW : CPE ratio of 1.02. Application of 40 litre water twice a week was found essential for establishment and early growth of coconut (cv. CRIC 60) in the dry zone of Sri Lanka (Liyange and Mathes, 1989).

The varieties of coconuts respond differently to varying soil moisture conditions. More than 4 decades of research in Sri Lanka have indicated that coconut cv. CRIC 65 is capable of producing a sustained higher yield than cv. CRIC 60 in the absence of adverse soil water deficit (Peries, 1994). Dwarf x West African Tall coconut hybrids planted in a dry climate with supplementary irrigation and NPK fertilizers gave copra yields of 4.1-4.3 t per ha per year in contrast to 3.4-3.6 t per ha per year recorded under low management input (Daniel *et al.*, 1991).

A seven-year trial with basin irrigation applied during dry periods at 82 gallons per palm weekly or fortnightly, or at 164 gallons per palm fortnightly indicated that total copra yield increased from 3488 to 5377 lb/ha due to weekly applications in drier years and from 5,011 to 6,311 lb/ha in wetter years (Abeywardena, 1979). In a three year trial, with three coconut cultivars, *viz.* Malayan Dwarf Yellow, Malayan Dwarf Green and Malayan Dwarf Red (13 to 16 year-old palms), irrigation on alternate days was found to be highly effective in enhancing the yield as compared to irrigation at fortnightly intervals.

Flood method of irrigation was traditionally being practiced in majority of coconut growing areas *viz.*, certain areas in Tamil Nadu, East and West Godavari district of Andhra Pradesh in India, where water supply is unlimited. About 50,000 to 75,000 l water was applied once in a week, depending upon the quantity of water available, soil type, climatic factor etc. Disadvantage of this irrigation method is wastage of irrigation water through deep percolation in porous soil while in clay soil it results in water stagnation leading to difficulty in carrying out the various cultural operations. In basin irrigation method channels are provided in between two rows and each basin is connected with the channel and water is applied in the basin of 1.8-2.0 m radius which is the active root zone of coconut. CPCRI recommends application of 200 l of water once in four days for the WCT palms in red sandy loam soils of the west coast (Dhanapal *et al.*, 1999). However, in this method also there will be some loss of water due to deep percolation, seepage and evaporation. This loss can be reduced if the basins are irrigated through hosepipe, and this also reduces water loss in transit.

Sprinkler or perfo-irrigation with 20 mm water is most suited to inter or mixed cropping system where the entire surface requires wetting. The quantity of water applied should be at least 75 percent of open pan evaporation. However, the initial investment is more and there is a possibility of clogging the small pores when the irrigation water is not clear. Among the irrigation system, drip irrigation is gaining importance. Drip irrigation is ideally suited for the widely spaced crops like coconut as it saves water, energy and labor with higher WUE. The irrigation efficiency of drip irrigation is 40-60 per cent higher than palms receiving basin irrigation. Based on the study conducted at CPCRI, it was concluded that the yield of coconut with drip irrigation daily @ 66 per cent of open pan evaporation (E_o) from December

to May was adequate and comparable to basin irrigation @200l per palm once in four days (Dhanapal *et al.*, 1999, 2004). Hence there is 34 per cent saving in water. The number of dripping points should be six for sandy soils and four for the other soil types (Figure 9.3). The rate of water application should be 2-3 l per hour per emitter. Studies on the effect of mulches and irrigation of young coconut plants in coastal Karnataka indicated better growth under drip irrigation and coir pith mulch (Uthaiiah *et al.*, 1989).



Figure 9.3: Drip Irrigation in Littoral Sandy Soil.

8. Fertigation

Being a perennial crop, coconut demands a continuous supply of nutrients from the soil. However, the general recommendation of fertilizer application to soil fails to supply nutrients continuously as it will leach or evaporate after some time of application leading to lesser fertilizer use efficiency. This necessitates finding suitable ways to increase the fertilizer use efficiency. Drip fertigation is one such best option that was emphasized by many workers (Shigure *et al.*, 1999; Mohammed, 2004). Fertigation is a method where nutrients are applied through irrigation water. Fertigation is more suitable and economical through drip irrigation where fertilizers are applied exactly and uniformly to the wetted root zone. This remarkably increases the efficiency of applied fertilizer, which allows reducing the quantity of fertilizer applied. This not only reduces the production costs, but also lessens the potential of groundwater pollution caused by the fertilizer leaching. Fertigation allows application of required quantity and concentration of nutrients to meet the actual nutritional requirement of the crop throughout the growing season. Water soluble fertilizers like Urea, Di Ammonium Phosphate and Muriate of Potash and liquid fertilizers are supplied through drip irrigation. Generally, liquid fertilizers will not clog the drippers but, these fertilizers are costly. The fertilizers are applied in six equal splits from December to May at monthly interval. The findings of the CPCRI indicate that 50 per cent of RDF applied through drip fertigation is sufficient to produce yield equivalent of 100 per cent of the RDF through soil application

(Subramanian *et al.*, 2012). The study conducted in red sandy loam with low in available nitrogen (253 kg N ha^{-1}) and medium in available phosphorous ($24 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) and potassium ($295 \text{ kg K}_2\text{O ha}^{-1}$) indicated a fertilizer saving of 25 per cent is possible by adopting fertigation with 75 per cent NPK through drip irrigation. The number of bunches and female flowers per palm, nut and copra yield per palm and monetary returns are comparable to fertigation of 100 per cent NPK through drip irrigation and conventional method of 100 per cent NPK through soil application (Basavaraju *et al.*, 2014).

9. Nutrient Management

Regular manuring right from the first year of planting is essential for good vegetative growth, early flowering and bearing and high yield of coconut palms. The type of fertilizer and rates to be applied should be decided by the nutrient elements exported, losses by leaching, fixation in soil and to increase the concentration in the soil to an adequate level. Sometimes less has to be applied or no applications are required at all if the soil has sufficient quantities. To give an example, if soil available P is less than 10 ppm, full recommended dose of $320 \text{ g P}_2\text{O}_5/\text{palm}/\text{year}$ may be applied and for a soil test value of 10 to 20 ppm, 50 per cent of the same may be applied. For soil test values of more than 20 ppm, P application can be skipped. This choice is guided by leaf analysis, which proves to be remarkably accurate with coconut. Though critical levels have been determined they can vary substantially from one situation to another.

9.1. Application of Chemical Fertilizers

The practice of application of fertilizers in terms of quantity, application method and time varies from place to place. The fertiliser requirement of coconut in laterite soils was found to be 500 g N , $250 \text{ g P}_2\text{O}_5$ and $1250 \text{ g K}_2\text{O}/\text{palm}/\text{year}$ and that of the reclaimed marshy soils of the backwater regions of Kerala was found to be 250 g N , $340 \text{ g P}_2\text{O}_5$ and $680 \text{ g K}_2\text{O}/\text{palm}/\text{year}$. The general recommendation from C.P.C.R.I. for fertilising the adult bearing palms is to apply 500 g N , $320 \text{ g P}_2\text{O}_5$ and $1200 \text{ g K}_2\text{O}/\text{palm}/\text{year}$ in two split doses namely, one-third of the above dosage during May-June (pre-monsoon) and two-third during September-October (after the cessation of rains) (Nelliat, 1972). Under average management of coconut gardens, a minimum of 340 g N , $170 \text{ g P}_2\text{O}_5$ and $680 \text{ g K}_2\text{O}/\text{palm}/\text{year}$ may be applied in two splits as above (Anon., 1989). In Philippines, the fertilizer requirement is 400 g N , 131 g P , 1000 g K , 900 g Cl , 300 g Mg and 240 g S per palm per year. The fertilizers are applied in splits, the first half at the start of the rainy season and the remaining half, six months after or about a month before the end of the rainy season. In areas with almost even distribution of rainfall throughout the year, the first half of fertiliser is applied anytime and the remaining half six months later. For palms of bearing age, the annual rate of fertilisers are applied in one application for areas with an even rainfall distribution (one-and-a-half to three dry months) and split application for areas with distinct dry and rainy seasons. In Sri Lanka, the fertilizer requirement is $1.1 - 1.5 \text{ kg Sulphate of Ammonia}$, $0.3 - 0.6 \text{ kg Saphose Phosphate}$ and $0.9-1.6 \text{ kg Muriate of Potash}$ per palm per year.

In Philippines, the recommended fertilizer is uniformly broadcast in the base of the palm after weeding within a radius of 0.5 to 0.75 m for young and 1 to 1.5 m for bearing palms. The applied fertilizer will be incorporated to a depth of 5 to 8 cm with the suitable digging tool. This is necessary for nitrogenous fertilisers (like ammonium sulphate) to minimise/eliminate possible losses through ammonia volatilisation. For strongly sloping and hilly areas, fertilisers are equally distributed in 10 to 12 holes (10 to 12 cm deep and 7 to 10 cm wide) dug around the base of palm within 1 to 2 m radius. In India, one-third of the recommended dose is applied after the receipt of summer showers around the palms within a radius of 1.8 m and forked in. Circular basins of 1.8 radius and 25 cm depth are dug during August-September and green leaf or compost at the rate 30 kg per palm is spread in the basin. The two-third of the recommended dose of fertilizers is applied over the green leaf or compost and covered with soil. It is always advisable to test soil in the coconut garden periodically (once in 5 years) and the type and dose of fertilizer should be decided based on the soil test results from an existing coconut garden soil sample should be taken from the basin of the palm 1.5 m away from the trunk.

Among the three major nutrients, coconut is a heavy feeder of potassium. Supplementing potassium in the soil increases yield substantially and also it increases the resistance of coconut to diseases and pests. Experimental results revealed that palms receiving a regular dose of fertilizers bear fruit at the fifth year of planting while unfertilized palms needed eight years to bear. While nitrogen contributed only an eight per cent increase in copra yield, potassium contributed about 25-39 per cent increase. Coconut is a lime loving plant (Fremond *et al.*, 1966). However, calcium application had no influence on Ca content in leaves and yield (Manciot *et al.*, 1979). But some instance of increase in yield due to calcium application has been reported. Mg and S are important so far as growth and productivity of coconut is concerned, but both these nutrients are almost deficient in most of the coconut growing soils in humid tropics. In this context, application of $MgSO_4$ @ 500 g/palm is recommended.

Among micronutrients copper, chlorine, boron, zinc, iron, manganese and molybdenum are important for coconut productivity. Acid laterite and lateritic soils are deficient in Zn, B and Cu while Fe and Mn are high and even reach toxic level. In case of black soil availability of micronutrient barring Fe and Mn is high, whereas alluvial soils contain optimum amount of all the micronutrients required. The application of micronutrient to the soil should be judiciously planned. Any excess supply of these should be avoided to eliminate chronic problem of toxicity. Soil and tissue analysis should be the basis for application of micronutrients. Boron deficiency is commonly noticed in many areas. Application of 100 g Borax at bimonthly interval till remission of deficiency symptoms is recommended. However, in root (wilt) disease affected area, application of borax 120-180 g/plant with husk burial is recommended. In Sri Lanka, 10 per cent solution of sodium borate as foliar spray at every 4 days up to one month is recommended for remission of B deficiency.

9.2. Organic Nutrient Management/Organic Farming

Organic manures are important in sustaining soil fertility and productivity, especially in a perennial crop like coconut. Application of organic matters like green

leaf manuring, cattle manure etc. are practiced traditionally for coconut. However, due to the non-availability of land exclusively for cultivating green manure crops and also the limited supply of cattle manure for use as organic manure, the practice is being discontinued in coconut cultivation. Research efforts have resulted in development of organic farming technologies based on organic and bio-inputs for nutritious and soil health management (Joshi, 1982; Prabhu *et al.*, 1998; Thomas *et al.*, 2001).

9.2.1. Coconut Basin Management with Nitrogen Fixing Legumes

Atmospheric nitrogen fixed symbiotically by legume-Rhizobium association can form an important source of nutrients and organic manure for coconut palms (Thomas *et al.*, 2012). The basin area of 1.8 m radius around the bole of coconut palm is generally left unutilized by most of the farmers for any other purpose. Leguminous green manure crops such as *Pueraria phaseoloides*, *Mimosa inoisa*, *Calopogonium mucunoides* and *Vigna unguiculata* can be successfully raised in coconut basins (Figure 9.4). The biomass production and nitrogen contribution by green manure legumes and their influence on soil fertility parameters vary with soil type, climatic factors and type of green manure raised on an average they produce about 15-20 kg green matter/basin and their incorporation can contribute around 100-150g nitrogen/basin and other major nutrients as well as enhance the population of specific groups of beneficial micro-organisms (bacteria and nitrogen-fixers) in the basin thereby improving the soil fertility. The significant increase in the population of micro organisms and the enzymatic activity modifies the soil environment for the benefit of palm growth. The method of cultivation of green manure in coconut basin is simple, inexpensive and can be adopted even by small farmers. With the continuous cultivation of legumes, it is possible to augment soil organic matter for sustaining soil fertility and improving coconut yield. Sow the green manure seeds during May-June around the palm basins and uproot when one or two plants start flowering and incorporate the biomass. The nutrient level increases considerably as the biomass start decomposing.



Figure 9.4: Basin Management with *Pueraria phaseoloides*.

9.2.2. Green Manuring in Coconut

Green leaf manuring has been a common practice among the coconut growers since time immemorial. Green leaves from the adjoining forest areas/bulk areas were being collected and incorporated in the basins dug around the coconut palms in the month of August-September. But in view of the shortage of forest, the practice has become difficult to follow year by year. Under such circumstances, green manuring, which is the practice of raising a legume and subsequently turning it down in soil after it reaches the maximum vegetative growth to increase the soil fertility, has great potential.

The selection of a green manuring crop is important for highest benefits. It should be high yielding, quick growing to compete with the weeds in the initial growth stages and adaptable to the climatic condition. Some of the green manuring crops viz., *Sesbania*, *Calopogonium*, *Pueraria*, *Tephrosia*, *Crotalaria*, *Mimosa*, Horse gram and cowpea can be grown in the interspaces of coconut garden when coconut is grown as monocrop (Figure 9.5).

9.2.3 Glyricidia Alley Cropping in Coconut for Biomass Generation

Generation of large quantities of nitrogen rich biomass is also possible through the cultivation of the fast growing perennial leguminous green leaf manure tree

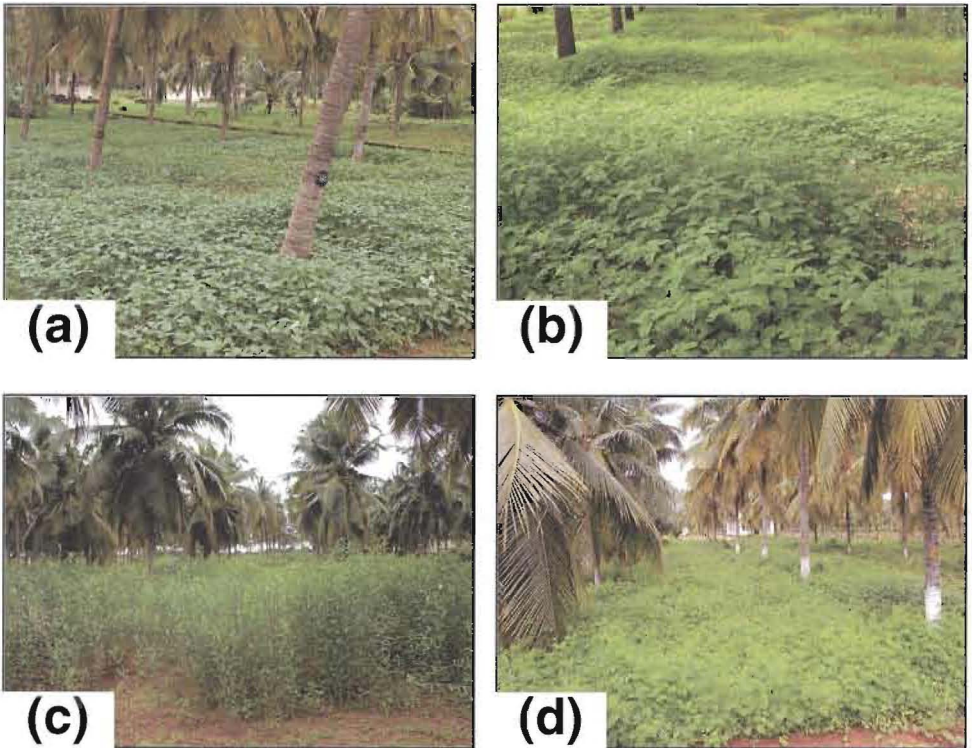


Figure 9.5: Green Manure in the Interspace of Coconut, a) Cowpea, b) Daincha, c) Sun hemp, d) Mimosa.

crop, *Glyricidia* in the coconut plantations (Figure 9.6). This can very well be grown along the borders of coconut plantation and can generate adequate quantities of nitrogen rich green leaves. It can also be raised in littoral sandy soils where no other green manure can establish. The tree is propagated either through vegetative cuttings or seeds one meter long stem cuttings or 3 to 4 months old seedlings raised in poly bags/raised beds can be used for planting. It is preferable that the planting season coincides with the monsoon (South West/North East monsoon) for better establishment. Spacing of 1m x 1m can be adopted. Two rows of glyricidia can be planted along the boundary of coconut garden in a zig-zag manner. The stem cuttings or seedlings are to be planted in an upright position in pits of 30 cm³. For better establishment, a basal dose of 50 g of rock phosphate per pit may be applied. Height of the plants should always be maintained at 1m by pruning. There are no major pest and diseases afflicting *Glyricidia* and hence, no plant protection measures are required. Pruning can be started one year after planting and at least thrice in a year. Studies conducted at CPCRI have indicated that the best growth and biomass of leaves could be obtained by planting of three rows of *Glyricidia*, at 1 x 1 m spacing between two rows of coconut, and pruning of leaves during February, June and October. This could produce around 8 t of biomass in one hectare of coconut garden. Application of *Glyricidia* prunings, from the interspaces of one hectare of coconut garden, to the palms could supply around 90 per cent, 25 per cent and 15 per cent of the requirement of N, P and K, respectively (Subramanian *et al.*, 2000).



Figure 9.6: Alley Cropping of *Glyricidia* for Green Manure.

9.2.4. Bioinoculants/Biofertilizers in Coconut

Bioinoculants are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed or soil application and designed to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment. Function-specific microbial groups such as nitrogen-fixers, phosphate solubilizers, plant growth promoting rhizobacteria (PGPR) and mycorrhizae are used as biofertilizers

in organic farming of coconut. These groups of microorganisms are responsible for nitrogen fixation, phosphate solubilization/phosphorus mobilization and production of plant growth promoting substances.

Plant growth promoting rhizobacterial bioinoculants have been developed which are important microbial resources for raising coconut seedlings in polybags. PGPR based bioinoculant, 'Kera Probio', a talc formulation of *Bacillus megaterium*, can be used for raising robust coconut seedlings. This bioinoculant possessed multiple plant growth promotion properties (George, 2013; George *et al.*, 2013) and was also found to be effective for vegetable crops such as tomato, brinjal and chilli (Khadeejath Rajeela *et al.*, 2014). Information on the genes involved in conferring the plant growth promotion traits was obtained by shotgun multiplexing using the 454-sequencing platform of whole genome (Gupta *et al.*, 2014). PGPR are known to influence plant growth not only by direct but also by indirect mechanisms such as suppression of bacterial, fungal and nematode pathogens by the production of various metabolites, by induced systemic resistance and /or by competing with the pathogen for nutrients or for colonization space, as well (Gupta *et al.*, 2000).

The inoculation of associative diazotrophs such as *Azospirillum*, *Arthrobacter*, *Azoarcus*, *Herbaspirillum*, *Bacillus*, *Burkholderia* and *Pseudomonas* enhance growth and vigour of polybag raised coconut seedlings. These bioinoculants effectively enhance root biomass and branching of the secondary roots of the coconut seedlings. Inoculation of PGPRs *Brevibacillus brevis* and *Bacillus coagulans* result in production of coconut seedlings with high seedling quality index (Gupta *et al.*, 2006). Coconut seedlings grown in polybags respond well to inoculation of biofertilizers of *Azospirillum brasilense*. The response is most conspicuous in the root biomass of coconut seedlings which is reflected in the number of roots, branching of roots and root dry weight (Reddy *et al.*, 2001).

The microbial inoculants are prepared by formulating living cells of beneficial microorganisms in suitable carriers. The carrier material prepared using the mixture of coir dust + soil + FYM (1:1:1 ratio) is highly suitable for production of biofertilizer of *Beijerinckia indica*. For formulating nitrogen fixing *Azospirillum brasilense* and phosphate solubilizing *Bacillus* sp. into bio-inoculants/biofertilizers, sterilized vermicompost is used as carrier material. The cell count at the time of preparation is maintained as per Bureau of Indian Standards (BIS) specifications. The recommended dose of biofertilizers for coconut is 100g of carrier based inoculant per palm. The biofertilizer is to be applied in the coconut basin, twice in a year (pre-monsoon and post-monsoon), by mixing with top soil followed by application of organic amendments. The application of *Bacillus* sp. and *Azoarcus* sp. as biofertilizer in the basins of adult coconut palms of Laccadive ordinary variety resulted in significant increase in nut as well as copra yield (Gupta, unpublished).

Organic amendments along with microbial inoculation elicits a greater level of plant growth response. Organic amendments such as vermicompost, coir pith compost, farm yard manure, neem cake, green manures etc. can be combined with microbial inoculants (Khadeejath Rajeela *et al.*, Unpublished). For additive effects, the compost prepared from coir-pith and other coconut wastes can be enriched with nitrogen-fixing bacteria like *Beijerinckia indica* and also phosphate-solubilizing

bacteria, for application in coconut basins. While applying biofertilizers, organic amendments such as vermicompost are added @20 kg/coconut palm. Also, the activities and positive effects of these beneficial microorganisms become more tangible in mixed cropping/ farming systems in which coconut and other component crops continually add plant residues to the soil which undergo organic recycling.

9.3. Recycling of on Farm Wastes

9.3.1. Availability of Organic Residues in Coconut Gardens

The availability of waste biomass from a well-managed coconut garden with 175 trees/ha has been estimated as 14 to 16 tons per hectare per year in the form of leaves, stipules, spathe, bunch waste and husk (Biddappa *et al.*, 1996). A considerable portion of husk is used for extraction of coir fibre. The by-product of coir processing factories, coir pith is usually dumped without any use. It has been estimated that 7.5 million tons of coir pith is available in the country from the various coir de-fibering units. The total availability of waste biomass from 1.94 million hectare of coconut plantation in the country has been estimated as 15.4 million tons annually. The natural decomposition of these wastes and the nutrient release are very slow due to the high lignin content and the nature of lignocellulose complex of the coconut waste. If they are recycled fully, this waste biomass can meet a major portion of nitrogen and a part of other nutrient requirement of crops. Recycling of coconut waste biomass is possible without affecting the prospects of husk or shell based industries. It also helps to replenish the nutrients exhausted by the palms internally without depending on the external sources.

9.3.2. Utilisation of Leaves and Husks as Fertiliser

It is known that one ha of coconuts (average of 150 palms) producing 12 to 14 leaves and 100 nuts/tree/year contains in the harvested produce the following amount of nutrients: 49 kg N, 7 kg P, 5 kg K, 5 kg Ca, 8 kg Mg, 11 kg Na, 64 kg Cl and 4 kg S. The husk contains 60 per cent of the K, 18 per cent of N and 26 per cent of Mg exported from the harvest. Thus to reduce the rates of fertiliser application and cost by 20 to 30 per cent and to maintain target yields, it is recommended that the farm wastes such as coconut husks and leaf fronds be left in the field to undergo nutrient leaching, decomposition and mineralization, and these nutrients become available for the crop eventually (Magat, 1993).

9.3.3. Vermicomposting of Coconut Palm Wastes

Vermicomposting involves using native species of earthworm (*Eudrilus eugeniae*) for conversion of biomass, into useful compost (Figure 9.7) (Prabhu *et al.*, 1998). Vermicomposting can be easily done *in situ* in coconut plantations using coconut leaves and other biomass including wastes from intercrops especially from banana. *In situ* recycling of coconut wastes by vermicomposting in trenches dug in interspaces of four coconut palms yield on an average recovery of 70 per cent in a composting period of 90 days. The average nutrient composition of the vermicompost recovered will be around 1.2-1.8 per cent N, 0.1-0.2 per cent P and 0.2-0.4 per cent K, 17.84 per cent organic carbon, and C/N of 9.95:1.00. Total microbial counts and beneficial microbial population will also be more in the coconut leaf



Figure 9.7: Recycling of Organic Wastes through Vermicomposting, a) Coconut leaves, b) *Eudrilus eugeniae*, c) Vermicompost.

compost as compared to the base material. This enables disposal of coconut wastes in a less expensive and eco-friendly manner, with the benefit of producing high quality organic manure in the coconut plantation itself. Various methods such as cement tanks, trenches as well as composting in the coconut basin itself can be adopted for vermicomposting wherein composting in the basins itself reduces cost incurred in transportation of leaves and application of vermicompost. The leaf dry matter production by tall coconut palms is around 32 kg/palm/year and hence the availability of leaf from one hectare of coconut plantation can be estimated as 5.6 t per hectare per year. In this manner all the leaves produced from one coconut palm can be converted into very good organic manure. This technology can be adopted in plantations with very limited irrigation facilities as only less number of pits or trenches are to be irrigated. The coconut waste used for oyster mushroom production is also found suitable for vermicomposting. The composted spent substrate contains higher levels of micronutrients such as Fe, Zn, Cu and Mn when compared to that of the untreated substrate. As vermicomposting can be carried out during most part of the year, it provides employment opportunities to farm families and self help groups as well as supports income generation.

Apart from coconut leaves, other agro-wastes like pineapple waste, banana pseudo stem and leaves and glyricidia green manure can also be effectively used along with coconut leaves for vermicomposting. Hence, the agro wastes generated from the coconut based cropping system can also be recycled efficiently in the

production system. For large scale composting, permanent cement or brick tanks can be constructed to provide an opportunity to maintain the appropriate quantity of food substrate, optimum moisture, temperature and other factors which are very essential for production of efficient and quality vermicompost. This will also give proper protection for the worms from predators like rodents, ants, birds and wild boars.

The water-soluble components from vermicomposting tanks may be collected as leachate by passing water slowly through the composting beds or by simple suspension of vermicompost in water. This vermiwash is honey brown in color with a pH of 8.5 and contains both major and minor nutrients in appreciable quantity. Growth promoting hormones like IAA and GA are also present in vermiwash. It is ideal for foliar applications after sufficiently diluting, based on the need. Vegetables and ornamental plants have been reported to respond very well to this treatment.

9.4. Coir Pith Composting

Coir pith is yet another organic material available in huge quantities from coir processing units. Extraction of one kilogram of coir fiber generates two kilograms of coir pith. Approximately 180 g of coir pith is obtained from the husk of one coconut. In India an estimated 7.5 million tonnes of coir pith is produced per annum. Coir pith hillocks are common in the neighborhood of fiber extraction units. This spongy cork like material left as such is normally resistant to biodegradation and is a source of environmental pollution. Though coir pith has a number of beneficial properties like improving soil physical properties and moisture holding capacity to a great extent, its direct utilization as manure is not advisable as it contains large amounts of lignin (75 percent) and phytotoxic polyphenols and less of nitrogen. Hence, it is to be applied to soil only after composting. Technologies for large scale composting of coir pith has been standardized at Central Plantation Crops Research Institute, Kasaragod with amendments like poultry manure, lime and rock phosphate @ 10 kg, 0.5 kg and 0.5 kg, respectively, for every 100 kg of coir pith as well as inoculation of biopolymer degrading micro-organisms at 0.2 per cent level (Thomas *et al.*, 2013). The raw coir pith with a C: N ratio of 100-112: 1 can be converted to an excellent organic manure with the C: N ratio of 17-24: 1 within a short period of 40-45 days. *Pleurotus* spp have the capacity to degrade part of the cellulose and lignin present in coir pith by production of enzymes *viz.*, cellulases and lactases (Nagrajan *et al.*, 1985). The lignin content also reduces considerably.

10. Weed Management

The diffused sunlight in coconut garden facilitates luxurious weed growth when coconut is grown as a monocrop. As a result, the unutilized space beneath the plantation becomes invaded by a wide range of perennial and annual weed species. Such weeds consistently compete with coconut palms for soil moisture, nutrients and sometimes light, especially when the palms are in the seedling stage, affecting its growth and yield. In areas with prolonged dry periods, competition for soil moisture may considerably affect the coconut yield (Liyanage and Liyanage, 1989). This competition can result in yield reduction of up to 18–20 per cent. Conversely, the cost of weed management has contributed approximately 15–20 per cent to the

total cost of production of coconut (Gunathilake *et al.*, 1993). Additionally, weeds obstruct routine cultural practices such as manuring, harvesting and collection of nuts. Weeds in the coconut plantations are managed in different ways, under the broad categories of integrated approach, mechanical, chemical and cultural methods (Liyanage and Liyanage, 1989).

In nursery application of coir pith immediately after seed nut sowing at 10 cm thickness as mulch resulted in the highest coconut seedling survival, early and more uniform nut germination (Uthaiyah and Lingaiah, 1989). Marimuthu and Bhaskaran (2003) reported that raising sun hemp in nursery thrice (each harvested at flowering stage) followed by one hand weeding at the 6th month was found to be the best management practice as it appreciably controlled the weeds and produced more quality seedlings (78.9 per cent), besides yielding green manure for manuring the adult coconut palms. In India manual weeding is followed to control weeds however, currently petrol/kerosene operated weed cutters are used for weed management especially, in the undulating terrains but it is time consuming, costly and tedious. Chemical method of weed control is more economic and less labour intensive. Chemical weed control is comparatively cheaper to hand weeding especially in places where the labour charges are high. Another advantage of chemical weed control in high rainfall zone and sloppy terrains is that the weeds killed by the chemical remains in the same place and forms a cover on the soil which prevents soil erosion during monsoon rains and also acts as mulch and conserves moisture in the summer. Glyphosate (N-(Phosphonomethyl)glycine) is a commonly used herbicide in coconut plantations. It is a non-selective post emergence herbicide which controls a wide range of monocotyledonous and dicotyledonous annuals, biennials and perennials (Boyall, 1998). Savithri *et al.* (1994) reported that the pre-emergence application of diuron 1.5 kg/ha, oxyfluorfen 0.2 kg/ha or raising cowpea as an intercrop could check the weed growth upto about three months. Subsequent weed growth could be effectively controlled by the application of paraquat 0.4 kg/ha or glyphosate 0.4 kg/ha. Among the different options available for weed management, integrated approach is more promising. An experiment conducted at CPCRI, Kidu, Karnataka revealed that the highest weed control efficiency in coconut was found with 2 4 D + Glyphosate + hand weeding, given in the month of May, June and September, respectively. Cover cropping with *Pueraria phaseoloides*, *Calapogonium mucanoides* and *Centrosema pubescens*, tillage and mulching (coconut leaf, husk, coir pith and plastic) are also effective measure in weed control.

11. Coconut based Cropping/Farming System

Studies have revealed that planting method and growth habit of sole coconut palms spaced at 7.5m x 7.5m use only 22.3 per cent of land area effectively while the average air space utilization by the canopy is about 30 per cent and solar radiation interception is 45-50 per cent which make them highly adaptable for crop diversification in the coconut plantation (Nelliath *et al.*, 1974). Making use of the underutilized soil space and solar radiation in pure stands, a variety of crops having different stature, canopy shape and size and rooting habit can be inter planted to form compatible combinations. Such intercropped plantations will intercept and utilize light at different Glyphosate (N-(phosphonomethyl)-glycine) and forage

soil at different strata maximizing biomass production per unit area of land, time and inputs. Due to the low income level from coconut monoculture and fluctuating coconut prices, high priority has been given to optimize the use of land and other resources for increasing the productivity of coconut.

The pioneering effort of CPCRI has resulted in the development of technologies for coconut based inter/mixed, multi-storied multi-species cropping systems and these are being widely adopted by the farmers. The high density multi-species cropping system and coconut-based mixed farming system, involving annuals/biennials/perennials grown in different tiers by exploiting soil and air space more efficiently and integrating with poultry and animal husbandry, helps to maximize profits and can even buffer the price crash of the main crop. The crops selected for a cropping system should be compatible with the main crop and it should have local demand.

11.1. Coconut based Farming System

Coconut in India is predominantly cultivated in small and marginal holdings. About 98 per cent of the coconut holdings in the country are less than 2.0 ha in size and more than 90 per cent of them are less than 1.0 ha in extent. Most of these holdings neither provide gainful employment opportunities for the family labor throughout the year nor generate sufficient income to meet the family requirement and also presently coconut growers are more exposed to economic risks and uncertainties owing to the rapid price fluctuations. In this context, it is needless to emphasize the importance of crop/enterprise diversification in coconut gardens. Mixed farming by raising fodder grasses such as hybrid napier or guinea grass along with leguminous fodder crops such as *Stylosanthes gracilis* in coconut gardens has been found to be profitable. Raising the above crops in one hectare of coconut garden can support four to five dairy animals. However, if hybrid Bajra Napier (Co4) is grown as an inter crop in coconut garden 8 to 10 animals can be maintained. In addition to the cattle, poultry, pisciculture and apiculture may be integrated depending upon the farmer's interest (Figure 9.8). The cattle and poultry manure generated from the system when applied to coconut garden improves the soil fertility considerably. Maintaining milch cows and other components in coconut garden helps the farmer to enhance his income and also provides additional employment to the family.

In a scientifically laid out farming system, unlike the traditional one, one ha of coconut based integrated farming system comprising coconut, pepper trailing on coconut trunk, banana in the interspaces of coconut, dairy unit (7 cows of Holstein Friesian and one Jersey), fodder grass (hybrid Bajra Napier Co 4), poultry (100 broiler birds/batch), and aquaculture (1000 fingerlings), recorded a yield of 23100 numbers of coconut, 15626 l of milk, 470 kg of broiler birds, 2360 kg of banana, 369 kg of pepper and 500 m³ of biogas with a net income of Rs. 5,50,214/ha/year (Maheswarappa *et al.*, 2001; Subramanian *et al.*, 2014).

11.2. Coconut based High Density Multi Species Cropping System

High density multispecies cropping system (HDMSCS) involves growing a large number of crops to meet the diverse needs of the farmer such as food,

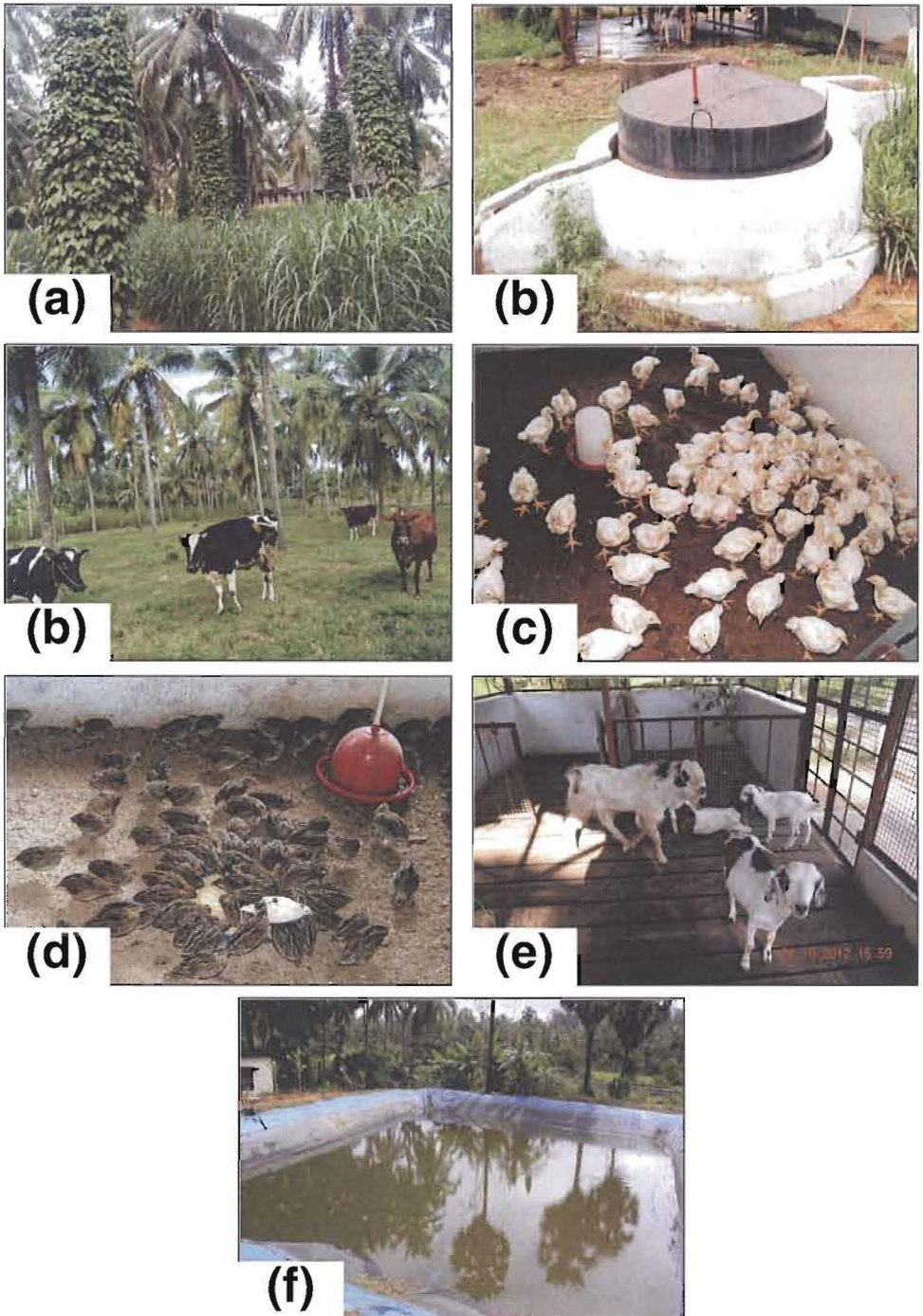


Figure 9.8: Coconut Based Farming System,
 a) Coconut, black pepper and grass, b) Dairy with biogas unit,
 c) Poultry unit, d) Quail bird, e) Goat unit, f) Fish pond.

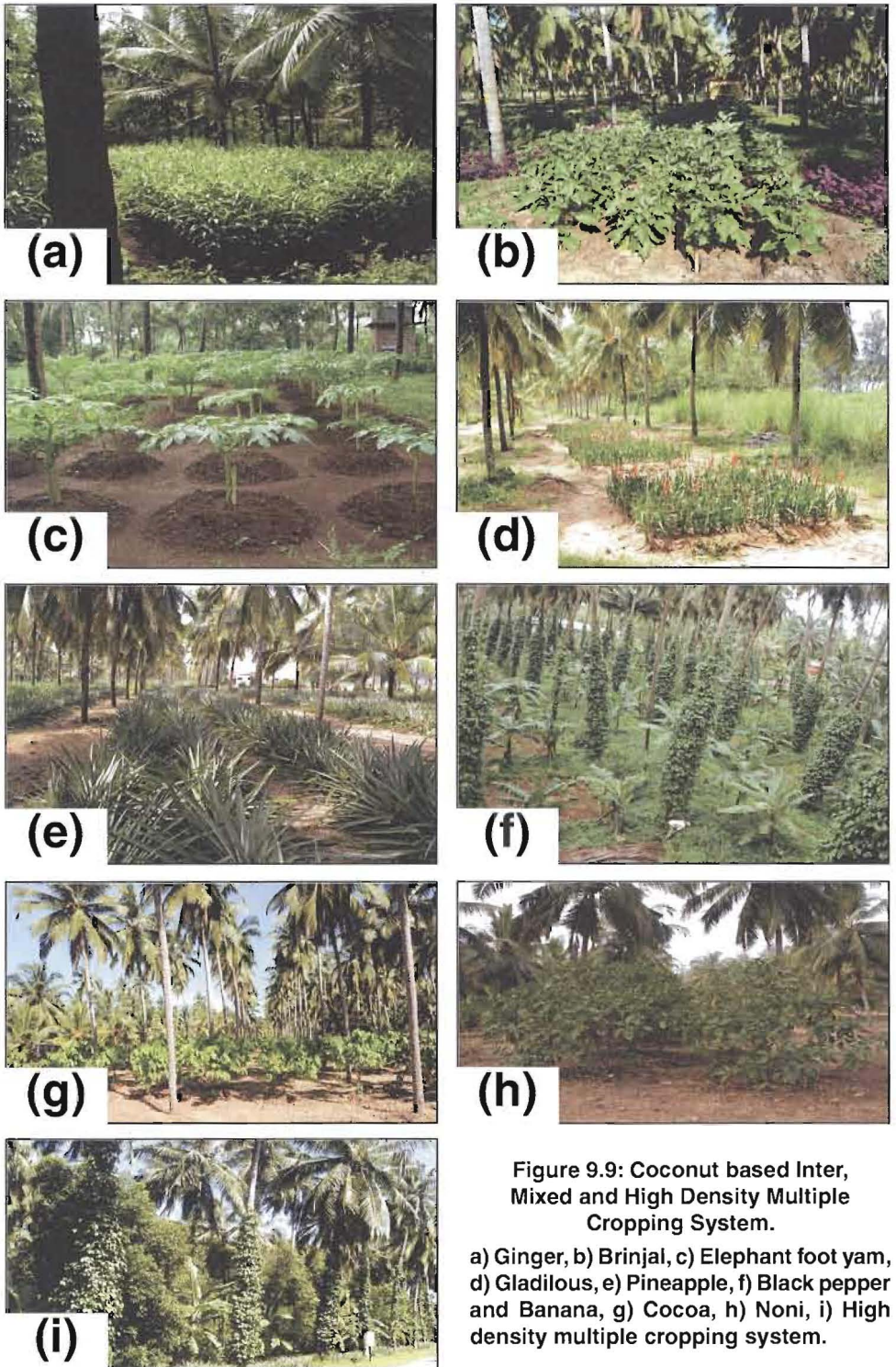


Figure 9.9: Coconut based Inter, Mixed and High Density Multiple Cropping System.

a) Ginger, b) Brinjal, c) Elephant foot yam, d) Gladiolus, e) Pineapple, f) Black pepper and Banana, g) Cocoa, h) Noni, i) High density multiple cropping system.

fuel, timber, fodder and cash. This is ideally suited for smaller units of land and aims at maximum production per unit area of land, time and simultaneously ensuring sustainability. This system includes annuals, biennials and perennials. The crops selected include cash crops, food crops and fodder crops. The biomass other than the economic part is recycled within the system from the experimental plot on HDMSCS maintained at CPCRI Kasaragod, which involves coconut and other crops like banana, pineapple, Pepper, clove and nutmeg, it is observed that coconut yield in the high density multi species cropping system was on par with fully organic application or 1/3rd recommended chemical fertilizer and recycling biomass (vermicompost) + biofertiliser + green manuring + vermiwash or 2/3rd recommended chemical fertilizer and recycling biomass (vermicompost) (Figure 9.9). The yield ranged from 177 to 188 nuts palm⁻¹ yr⁻¹. Black pepper yield did not differ significantly among the treatments and ranged from 2.97 to 3.58 kg vine⁻¹. Cinnamon quill yield of 1.5 to 1.7 kg tree⁻¹ was recorded. Banana yield did not differ significantly among the treatments and ranged from 8 to 9 kg bunch⁻¹ (var. Kadali) and 12 kg to 16 kg bunch⁻¹ (var. Robusta). The copra yield did not differ significantly among the treatments and ranged from 4.7 to 5.2 t ha⁻¹ (Maheswarappa *et al.*, 2013; Subramanian *et al.*, 2016).

Besides, 25 tonnes of organic wastes are also made available per ha which can be recycled and applied to the crops as vermicompost. In HDMSCS, if organic recycling is effectively carried out, the chemical fertilizer input for coconut can be reduced to two third of the recommended dose. In a high density multispecies cropping system with coconut and 17 component crops, the nutrient budget and balance studies indicated considerable build up of P and K in the system as a whole, while N and Mg got depleted. The depletion of Mg was uniform irrespective of the levels of fertilisers (one-third, two-third and full dose of recommended fertilisers for component crops and coconut) applied while the addition of full dose of fertilisers reduced the N depletion rate. The heavy build up of P and K in the system suggests the adequacy of one-third dose of P and K for maximum system productivity (Cecil and Khan, 1993).

11.3. Intercropping of Medicinal Tree Plants in Coconut Garden

The WHO compiled 20,000 medicinal plants used in different parts of the globe. Among these over one hundred botanicals plants are reported to have consistently larger market and are traded in major drug markets in the world. In this juncture, a field experiment was conducted at Central Plantation crops Research Institute, Kasaragod, Kerala during 2003-2004 to 2014-2015 with intercropping of different perennial medicinal trees. The stem yield of medicinal plants *viz.*, *Stereospermum sauveolens* (Poopathri), *Oroxylum indicum* (Palakappayani), *Gmelina arborea* (Kumizhu), *Saraca asoca* (Asoka), *Aegle marmelos* (Koovalam) and *Premna serratifolia* (munja) were 54.06, 6.39, 25.52, 1.66, 12.71 and 3.47 t ha⁻¹ respectively. The root yield was recorded as 9.69, 3.22, 17.89, 0.35, 5.46 and 3.25 t ha⁻¹, respectively. The coconut yield in the experimental plot during the period (2013-14) was 128 nuts/palm which showed 21 per cent increase in yield over pre experimental yield of 101 nuts/palm during 2000-02 indicating the positive effect of mixed cropping with medicinal tree species.

Benefits of Cropping/Farming System

- ☆ It functions as a main source of income and also reflect on well being of farm families by providing food and nutritional security
- ☆ It provides a favourable and ecologically stable intensive and sustainable agricultural production which is mainly possible by efficient utilization of natural resources
- ☆ In this system, coconut garden is covered through crops which minimizes the soil and water loss through surface runoff, increases the rain water infiltration and storage, apart from this by reducing weed growth, loss of nutrients and soil moisture reduces.
- ☆ It acts as an insurance against crop failure, stabilizes the economic income of farmers and considerably enhances the employment generation.
- ☆ It gives opportunity for organic recycling which intern helps in soil fertility build up

12. Soil and Moisture Conservation Measures

Proper soil and moisture conservation practices are essential for ensuring sustainable production especially when coconut is grown under rainfed condition with undulating terrain and sloppy conditions.

12.1. Mulching Coconut Basins with Leaves, Coir Pith etc.

Mulching the coconut basin helps to reduce soil temperature and evaporation from the soil surface. Coconut leaves, husk and coir pith could be utilized as mulches to reduce the loss of soil moisture and create conditions for proper root growth and proliferation of soil flora and fauna (Figure 9.10) (Maheswarappa *et al.*, 1998). Decomposition of the mulches after a period of time results in enrichment of soil organic matter pool. Coconut husk can hold moisture to the tune of three to five times of its weight. Approximately 250-300 husk required for one coconut basin. Mulching is usually done up to a radius of 2 m. Two layers of husk may be buried in the coconut basin with the concave side facing upwards. These layers facilitate absorption of moisture. Above this another layer of coconut husk is placed with the convex side facing upwards to arrest evaporation. The effect of mulching lasts for about 5-7 years. Besides conserving soil moisture, coconut husk is an important organic material and a good source of plant nutrients on dry weight basis, the average composition of material is 0.23 per cent N, 0.04 per cent P_2O_5 , 0.78 per cent K_2O , 0.08 per cent Ca and 0.05 per cent MgO on an average husk constitutes 45 per cent of the weight of nut and on this basis, a nut weighing 1,000 g will have 450 g of husk with 20 per cent moisture.

12.2. Coconut Husk Burial in the Interspaces of Coconut Garden

Burial of the husk in the soil act as a water reservoir and also supply palms with small amount of potash present in it. A fully soaked husk is able to retain about 5-6 times of its weight of water and is made available to the palms during summer season. Trenches of 50 cm width x 50 cm depth and convenient length would be

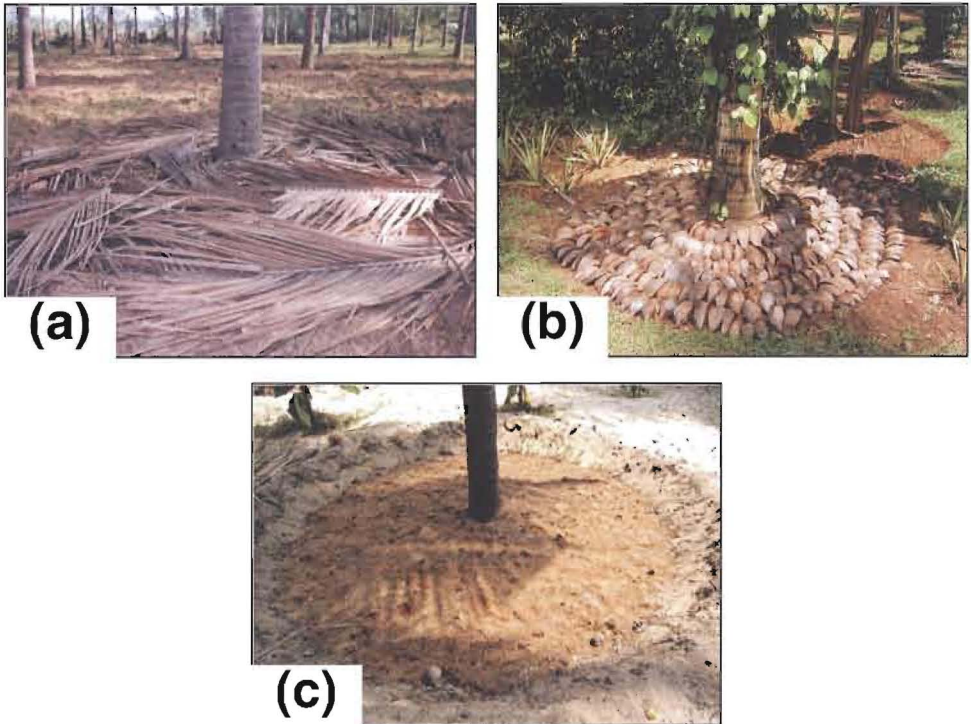


Figure 9.10: Moisture Conservation

a) Mulching with coconut leaves, b) Mulching with husk, c) Mulching with coir pith.

made in between two rows of coconut palms (Figure 9.11). These trenches would then be filled with coconut husk. Coconut husks need to be filled in layers with the bottom layers facing up and top layer facing down. A bund of 20 cm height and suitable width (>50 cm) is made at the downstream using the excavated soil. Two layers of pineapple plants would be planted on the bund with a spacing of 20 cm plant to plant and 20 cm row to row. Pineapple plants would stabilize the bund and provide additional income to the farmer. The runoff water from the upper side would be collected in the trenches. Soil particles would also get collected in the trench along with the runoff water (Dhanapal *et al.*, 2005).

12.3. Half-moon Bund around Coconut Basin Reinforced with Pineapple

This measure is to be taken up where there is mild slope (15-20 per cent). Here a flat basin with a slight inward slope towards upstream is made by excavating soil from the upstream side and filling the excavated soil at the downstream side. After making the basin a bund of 30 cm height and >50 cm width is made at the downstream side of the coconut using the excavated soil. Two layers of pineapple plants would be planted with a spacing of 20 cm row to row and 20 cm plant to



Figure 9.11: Husk Burial in Coconut Interspace.

plant on the bund (Figure 9.12). The bund prevents runoff and water gets collected within the basin and percolates down. Pineapple would help to protect the bund and stabilize the same in addition to giving fruit yield (Dhanapal *et al.*, 2005).

12.4. Trench Filled with Coconut Husk

This measure is to be taken up where the land slope is high. Trenches of 50 cm width x 50 cm depth and convenient length would be made in between two rows of coconut palms. These trenches would then be filled with coconut husk. Coconut husks need to be filled in layers with the bottom layers facing up and top layer facing down. A bund of 30 cm height and suitable width (>50 cm) is made at the downstream using the excavated soil. Two layers of pineapple plants would be planted on the bund with a spacing of 20 cm plant to plant and 20 cm row to row



Figure 9.12: Half Moon Bund around Palm.

(Figure 9.13). Pineapple plants would stabilize the bund and provide additional income to the farmer. The runoff water from the upper side would be collected in the trenches. Soil particles would also get collected in the trench along with the runoff water. Coconut husk retains the moisture and makes it available for plants during summer months (Dhanapal *et al.*, 2005).



Figure 9.13: Trench Filled with Coconut Husk.

12.5. Catch Pits with Pineapple Border

Catch pits can be constructed on all slopes to conserve soil and water. Though there is no standard dimension for catch pits, we may go for catch pits of 1.5 m length \times 0.5 m width \times 0.5 m depth. A bund is to be made at the downstream using the excavated soil and pineapple plants planted on it (Figure 9.14). This pit also may or may not be filled with coconut husk. If it is without husk, periodic measurement of the dimension of the pit gives the amount of soil collected inside the pit, a direct measurement of soil erosion (Dhanapal *et al.*, 2005).



Figure 9.14: Catch Pit with Pineapple Border.

12.6. Cover Crops as Green Manure and to Reduce Soil Erosion

Crops like *Calopogonium*, *Pueraria*, cowpea etc., can be grown as cover crop in coconut gardens where mild to steep slopes are prevalent. Growing of cover crops protects the soil from beating effect of rain especially during high intensity of rainfall thus helping in the percolation of the rainwater. This also helps in preventing the soil as well as nutrient loss.

13. Harvest

Fully matured 1112 month old nuts are harvested. Coconuts are harvested at varying intervals in a year. The frequency varies depending upon the yield of palms. Usually, the nuts are harvested 6 to 10 times in a year. In well maintained and high yielding gardens, bunches are produced regularly and harvesting is done once in a month. Skilled personnel are traditionally employed for climbing palms for harvesting nuts. Nowadays, lack of availability of skilled climbers for harvesting operations is a serious problem experienced by coconut farmers. A simple palm climbing device invented by a farmer from Kannur district of Kerala is gaining popularity.

14. Conclusion

In the evolving trade liberalization regime, sustaining coconut cultivation as a profitable enterprise is extremely challenging one way to achieve this goal is through reduction in cost of production or in other words increasing the net returns. The scientific cultivation of coconut by adopting the improved technologies such as fertigation, drip irrigation, soil test based nutrient application, green manuring and recycling wastes and proper soil and water conservation techniques will improve the coconut production with less cost. The cropping/farming system models of CPCRI have conclusively proved that the scientifically designed coconut-based farming system is not only capable of generating higher income, but also enhancing the employment potential of small-holders.

References

- Abeyawardena, V. (1979). Influence of watering on the yield of coconut. *Ceylon-Coconut Quarterly*, **30**: 91-100.
- Aiyadurai, S.G. (1954). A note on the nursery studies on coconut seedlings. *Indian Coconut Journal*, **7**: 156-63.
- Anonymous. (2012). Annual Report (2011-12), Central Plantation Crops Research Institute, Kasargod, India.
- Basavaraju, T.B., Bhagya, H.P., Prashanth, M., Arulraj, S. and Maheswarappa, H.P. (2014). Effect of fertigation on the productivity of coconut. *Journal of Plantation Crops*, **42**: 198-204.
- Biddappa, C.C., Upadhyay, A.K., Hegde, M.R. and Palanuswami, C. (1996). Organic matter recycling in plantation crops. *Journal of Plantation Crops*, **24**: 71-85.
- Boyall, L.A. (1998). The control of perennial weeds. In: *Recent Advances in Weed Research* (ed. by Fletcher W.W.). The Gresham Press, Surrey. pp.141-166.
- Cecil, S.R. and Khan H.H. (1993). Nutritional requirement of coconut and coconut based farming systems in India. In: M.K. Nair, H.H. Khan, P. Gopalasundaram, E.V.V. Bhaskara Rao (Eds.), *Advances in Coconut Research and Development*. Oxford and IBH publishing Co. Pvt. Ltd. New Delhi. pp. 257-275.
- Child, R. (1974). *Coconuts*, Second ed. Longman, London, 355p.
- CRI. (1954). Selection of seed coconut. Leaflet No.1. Coconut Research Institute, Sri Lanka.
- Cooke, F.C. (1936). The coconut industry in Phillipine Island. S.S and F.M.S. Dept. *Agric. Gen. Cir. Bull.*, **23**: 101.
- Copeland, E.B. (1931). *The coconut*. Macmillan and Co., London.
- Cosico, W.C. and Fernandez, N.C. (1983). Effect of some land qualities and soil properties on productivity of coconut in the Philippines. *Philipp. J. Cocon. Studies*, **8**: 25-30.
- Dhanapal, R., Subramanian, P. and Maheswarappa, H.P. (1999). Methods of Irrigation in Coconut Garden. *Indian Coconut Journal*, **4**: 4-7.

- Dhanapal, R., Maheshwarappa, H.P. and Subramanian, P. (2002). Influence of drip irrigation on growth, nut characters and yield of coconut in littoral sandy soil. *CARD*, **XVIII**: 1-23.
- Dhanapal, R. (2004). Irrigation management in coconut plantation. *J. Indian Soc. Coastal Agric. Res.*, **22**: 81-85.
- Dhanapal, R., Maheshwarappa, H.P. Sairam, C. V., Subramanian, P. and Upadhyay, A. K. (2004). Influence of drip irrigation on growth and yield of coconut (*Cocos nucifera* L.) in laterite soil. *Journal of Plantation Crops*, **32**: 26-30.
- Dhanapal, R., Mathew, A.C. and Palaniswami, C. (2005). Efficacy of soil and water conservation measures in coconut plantations of West Coast Region. *Indian Coconut Journal*,: 3-6.
- Daniel, C., Adje, I. and Vihoundje, F. (1991). Dwarf x Tall coconut hybrid performance in a dry climate with supplemental irrigation. *Oleagineux*, **46**: 13-22.
- Fremont, Y., Ziller, R. and M.de Nuce De Lamothe. (1966). The Coconut Palm. International Potash Institute Berne, Switzerland.
- George, P. (2013) Studies on Plant Growth Promoting Rhizobacteria mediated growth promotion in Coconut (*Cocos nucifera* L.). *Ph.D.*, University of Mangalore, Mangalore, India.
- George, P., Gupta, A., Gopal, M., Thomas, L. and Thomas, G.V. (2013) Multifarious beneficial traits and plant growth promoting potential of *Serratia marcescens* KiSII and *Enterobacter* sp. RNF 267 isolated from the rhizosphere of coconut palms (*Cocos nucifera* L.). *World J. Microbiol. Biotechnol.* **29**: 109 -117.
- Gunathilake H.A.J., Somasiri L.L.W., Peris T.S.G. and Fernando M.T.N. (1993). An appraisal of coconut grower's reaction and observation on Coconut Research Institute recommended cultural practices and other related issues. *CRI Report*, **2**: 89-96.
- Gupta, Alka, Gopal, Murali and Tilak, K.V.B.R. (2000) Mechanism of plant growth promotion by rhizobacteria. *Indian Journal of Experimental Biology*, **38**: 856-862.
- Gupta, Alka, Gopal, Murali and George V. Thomas. (2006) Bioaugmentation of *Cocos nucifera* L. seedlings with the plant growth promoting rhizobacteria, *Bacillus coagulans* and *Brevibacillus brevis* for growth promotion. Paper presented in the XXXVI Conference and Annual Meeting of European Society for New Methods in Agricultural Research, Sept. 10-14, 2006. Iasi, Romania,
- Gupta, A., Gopal, M., Thomas, G.V., Manikandan, V., Gajewski, J., Thomas, G., Seshagiri, S., Schuster, S. C., Rajesh, P., Gupta, R. (2014) Whole genome sequencing and analysis of plant growth promoting bacteria isolated from the rhizosphere of plantation crops coconut, cocoa and arecanut. *PLoS One* **9**(8), e104259. doi: 10.1371/journal.pone104259. (pp.1-14).
- Jeganathan, M. (1993). Coconut nutrition: experiences in Sri Lanka. In: M.K. Nair, H.H. Khan, P. Gopalsundaram, E.V.V. Bhaskara Rao (Eds.), *Advances in Coconut Research and Development*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. pp. 299-311.

- John, C.M. (1949). Coconut cultivation. *Indian Coconut Journal*, 2: 63-76.
- John, C.M. (1952). *Coconut cultivation*. Indian Central Coconut Committee, Ernakulum, India.
- Joshi, O.P., Nambiar, C.K.B and Khan, H.H. (1982). Effect of organic manuring on some physical properties and water retention of coastal sand. *Phillipine J. Coconut Studies*, 7: 42-46.
- Khadeejath Rajeela, T.H., Murali Gopal, Alka Gupta, Ravi Bhat and George V. Thomas. (2014) Cross-inoculation studies with plant growth promoting rhizobacteria isolated from coconut and cocoa on yield of chilli and tomato and their rhizosphere properties. Paper presented in the International In: Book of Abstracts, Conference on Biotechnology and Bioengineering (ICBB-2014), Oct. 29-30 2014, Birla Institute of Technology and Science (Pilani), Dubai Campus, U.A.E. pp. 48.
- Krishnakumar, V. K. and Reddy, D.V.S. (2006). Production of polybag seedlings in coconut. *Indian Coconut Journal*: 17-19.
- Krishnamoorthy, R. and Premnathan, S. (1968). Saline-alkali soils adjoining sea coast and their reclamation in Madras State. *Indian Journal of Agronomy*, 13: 237-242.
- Liyanage, D.V. (1952). Report of the Acting Botanist. Ann. Rep. of the Coconut Research Scheme for 1950. Ceylon Govt. Sessional Paper, 14: 22-30.
- Liyanage L.V.K. and de Liyanage M.S. (1989). Weed control understorey weed management in coconut lands. *CORD*, 1: 48-56.
- Liyanaga, L.V.K. and Mathes, D.T. (1989). Effect of irrigation on establishment and early growth of coconut (var. CRIC 60) in the dry zone of Sri Lanka. *Cocos*, 7: 1-13.
- Magat, S. S. (1993). Coconut nutrition: experiences in the Philippines. In: M.K. Nair, H.H. Khan, P. Gopaldasundaram, E.V.V. Bhaskara Rao (Eds.), *Advances in Coconut Research and Development*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. pp. 277-298.
- Maheswarappa, H.P., Subramanian, P., Dhanapal, R., Gopaldasundaram, P. and Hegde, M.R. (1998). Influence of irrigation and mulching on soil moisture and soil temperature under coconut in littoral sandy soil. *Journal of Plantation Crops*, 26: 93-97.
- Maheswarappa, H.P., Hegde, M.R., Dhanapal, R., Sairam, C.V. and Vidhan Singh, T. (2001). Impact of integrated mixed farming system in coconut (*Cocos nucifera* L.) garden on coconut yield and economic analysis. *Indian Journal of Agronomy*, 46: 56-63.
- Maheswarappa, H.P., Dhanapal R., Subramanian, P. and Palaniswami, C. (2013). Evaluation of coconut based high density multi-species cropping system under organic and integrated nutrient management. *Journal of Plantation Crops*, 41: 130-135.

- Manicot, R., Ollagnier, M. and Ochs, R. (1979). Mineral nutrition and fertilization of the coconut around the world. *Oleagineux*, **34**: 499-510.
- Marimuthu R and Bhaskaran R. (2003). Sun hemp - an efficient intercrop for coconut nursery. *Madras Agric. J.*, **90**: 615-616.
- Mohammad, M.J. (2004). Squash yield, nutrient content and soil fertility parameters in response to fertilizer application and rates of nitrogen fertigation. *Nutrient Cycling in Agroecosystem*, **68**: 99-108.
- Nagrajan, R., Manickam, T.S., Kothandaraman, G.V., Ramaswamy, K. and Palaniswamy, G.V. (1985) Manurial value of coir pith. *Madras Agric. J.*, **72**: 533-535.
- Nelliath, E.V. (1972). NPK nutrition of coconut palm - a review. *Journal of Plantation Crops*, **1** (Suppl.): 70-80.
- Nelliath, E. V., Bavappa, K. V. A. and Nair, P. K. R. (1974). Multi-storeyed cropping. A new dimension in multiple cropping for coconut plantations. *World Crops*, **26**: 262-266.
- Pandalai, K.M., Sankarasubramoney, H. and Menon, K.P.V. (1953). Filter press mud as an ameliorant for coconut soil. *Indian Coconut Journal*, **7**: 20-25.
- Peries. (1994). Coconut breeding in Sri Lanka. In: Proceedings Workshop Standardization of Coconut Breeding Research Techniques, 20-25 June 1994, Abidjan, Ivory Coast. pp.
- Persley, G.J. (1992). Replanting the Tree of Life: Towards an International Agenda for Coconut Palm Research. CAB, Oxford, UK, 156p.
- Prabhu, S.R., Subramanian, P., Biddappa, C.C. and Bopaiah, B.M. (1998). Prospects of increasing coconut productivity through vermiculture technology. *Indian coconut Journal*, **29**: 13-18
- Rajagopal, V., Parthasarathy, V.A., Naresh Kumar, S., Reddy, D.V.S. and Iyer, R. (2006). Coconut. In: Parthasarathy, V.A., Chattopadhyay, P.K., Bose, T.K. (Eds.), *Plantation Crops*, Vol. 2., Naya Udyog Pub., Kolkata, India. pp. 1-178.
- Sankaranarayanan, M.P., Varghese, E.J. and Menon, K.P.V. (1958). A note on the tolerance of salinity by coconut palm. *Indian Coconut Journal*, **11**: 133-139.
- Sampson, H.C. (1923). The coconut palm. John Bale, Sons and Danielson Ltd., London.
- Saseendran, S.A. and Jayakumar, M. (1988). Consumptive use and irrigation requirement of coconut plantations in Kerala. *Journal of Plantation Crops*, **16**: 119-125.
- Savithri, K.E., Sreedharan, C. and Abraham, C.T. (1994). Weed Management in coconut - Banana Intercropping System. *Indian Journal of Weed Science*, **26**: 57-63.
- Shigure, P.S., Lallan Ram, Marathe, R.A., Yadav, K.P. and Ram, L. (1999). Effect of nitrogen fertigation as vegetative growth and leaf nutrient content of acid lime

- (*Citrus aurantifolia*, Swingle) in Central India. *Indian Journal of Soil Conservation*, **27**: 45-49.
- Smith, A.C. (1933). Practical seed selection of coconut. *Malaya. Agric. J.*, **21**: 265-271.
- Srinivasa Reddy, D.V., Dhanpal, R., Palaniswami, C. and Maheshwarappa, H.P. (1998). Effect of levels and methods of fertilization on growth and recovery of vigorous seedlings in WCT coconut nursery. *Journal of Plantation Crops*, **26**: 58-62.
- Subramanian, P., Biddappa, C.C., Maheshwarappa, H.P., Dhanpal, R. and Palaniswami, C. (2000). Growing of Glyricidia as green manure crop in coconut garden in littoral sandy soil. *Journal of Plantation Crops*, **28**: 373-380.
- Subramanian, P., Dhanapal, R., Mathew, A. C., Palaniswami, C., Upadhyaya, A. K., Nareshkumar, S. and Reddy, D.V.S. (2012). Effect of fertilizer application through micro irrigation technique on nutrient availability and coconut productivity. *Journal of Plantation Crops*, **40**: 168-173.
- Subramanian, P., Thamban, C. and Maheswarappa, H.P. (2014). Coconut based farming system for higher income and employment opportunities. *Indian Coconut Journal*, **8**: 24-28.
- Subramanian, P., Maheswarappa, H.P., Zachariah, T.J., Surekha, R., Selvamani, V. and Ravi Bhat. (2016). Performance of black pepper in coconut based high density multi species cropping system under different nutrient management. *Journal of Plantation Crops*, **44**: 90-95.
- Thomas, G.V., Prabhu, S.R., Subramanian, P. and Iyer, R. (2001). Organic farming technology in coconut. *ATIC series publications No.4, Central Plantation Crop Research Institute, Kasaragod, Kerala*.
- Thomas, G.V., Krishnakumar V., Subramanian, P. Murali Gopal and Alka Gupta. (2012). Organic farming in coconut - feasibility, technological advances and prospects. *Indian Coconut Journal*, **LV(7)**: 22-31.
- Thomas, G.V., Palaniswami, C., Prabhu, S.R., Murali Gopal and Alka Gupta. (2013). Co-composting of coconut coir pith with solid poultry manure. *Current Science*, **104**: 245-250.
- Uthaiyah, B. C., Lingaiah, B. and Balakrishna Rao, K. (1989). Studies of the effect of mulches on coconut seedling establishment. *Indian Coconut Journal*, **20**: 7-8.
- Verghese, E.J., Krishna Marar, M.M. and Thomas, P.K. (1953). Preliminary Studies on the variation in moisture coconut soils. *Indian Coconut Journal*, **6**: 49-56.
- Wardlaw, H.H. and Mason, F.R. (1936). An account of irrigation and drainage control for an area of dwarf coconuts. *Malaya. Agric. J.*, **24**: 421-31.